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3D wake measurements from a scanning wind lidar in combination with a fast wind field reconstruction model

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High-resolution lidar wake measurements are part of an ongoing field campaign being conducted at the Scaled Wind Farm Technology (SWiFT) facility[1] by Sandia National Laboratories and the National Renewable Energy Laboratory using a customized scanning "DTU SpinnerLidar"[2] from the Technical University of Denmark. The purpose of the SpinnerLidar measurements at SWIFT is to measure the response of a V27 turbine wake to varying inflow conditions and turbine operating states.

Although our fast scanning SpinnerLidar is able to measure the line-of-sight projected wind speed at up to 400 points per second, a single lidar is in principle never able to measure all three wind components *(u, v, w)* in the scan plane at the same time. This limitation is often referred to as the "lidar cyclops syndrome". However, by processing the scanned line-of-sight wind speed data via a fast linearized Navier-Stokes CFD code "*Lincom Cyclop-buster model,*"[3] the corresponding 3D wind vector field *(u, v, w)* can be reconstructed under constraints for conservation of mass and momentum. The resulting model calculated line-of-sight projections of the 3D wind velocity vectors will become consistent with the line-of-sight wind speed measurements from the SpinnerLidar.

In this way, SpinnerLidar measured line-of-sight wake data from the SWiFT site at a range of downwind distances were used to calculate the three wind components *u(x, y)*, *v(x, y)* and *w(x, y)* in the turbine wake in a number of downwind crosswind scan planes. Fig.1 shows: a) the experimental setup, b) the line-of-sight measured wind field in a crosswind plane 66.2 m downwind, and 3) the corresponding Lincom model reconstructed axial wind component *u(x, y)*.

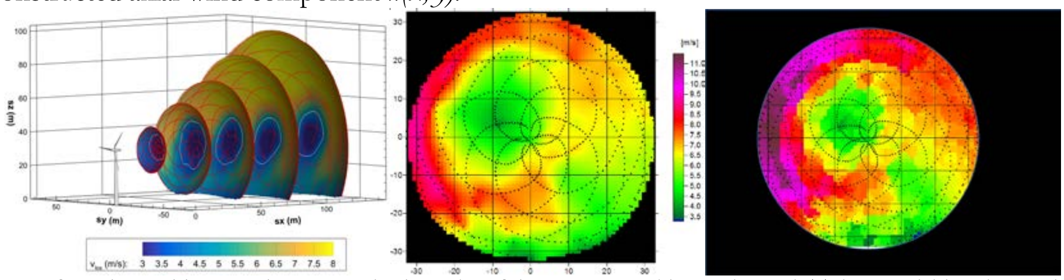

Fig.1. [Left]: SpinnerLidar scanning pattern in the wake of the V27 test turbine at the SWiFT site, overlaid on interpolated line-of-sight speed measurements; [Middle]: Line-of-sight wind speeds measured by the SpinnerLidar on Dec 2016 20:31:00 to 20:31:02 at 66.2 m downwind distance, interpolated on a 1*1 m grid facing the turbine, i.e. the turbine is behind the frame. [Right]: The corresponding Lincom Cyclop-buster wind field reconstructed axial wind field *u(x, y).*

The multiple line-of-sight speed measurements from the SpinnerLidar can be retrofitted to yield all three wind components on a standard PC in less than one second. The described wind field reconstruction methodology can thus be used in real-time for determination of the axial wind component flow, in the wake or in the inflow, from a single scanning lidar mounted on the turbine. The described methodology could potentially also be of benefit for providing upwind 3D wind data in real-time for advanced feed-forward turbine control.

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1. Herges, T. G., Maniaci, D. C., Naughton, B. T. & Mikkelsen, T. High resolution wind turbine wake measurements with a scanning lidar. In Proceedings of *EWEA Wake Conference May 30 - June 1 2017* (ed. EWEA).
2. Sjöholm, M. *et al.* Full two-dimensional rotor plane inflow measurements by a spinner-integrated wind lidar. in *EWEA 2013* PO.ID 250 (2013).t
3. Mikkelsen, T.; Astrup P.; van Dooren, M. F. The Lidar Cyclops Syndrome Bypassed: 3D Wind Field Measurements from a Turbine mounted Lidar in combination with a fast CFD solver. *In: ISARS 2016: 18. international symposium for the advancement of boundary layer remote sensing, Varna, June 2016.*